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ABSTRACT

Two studies, both part of a research program based on a theory of clinical problem solving behavior, used a computer to simulate a clinician interacting with a child having reading difficulties. The impact of routine cue collection on a clinician's performance is the focus of the first study; the process of hypothesis generation as it is affected by different certainty thresholds for considering a hypothesis is the subject of the second. The results of these studies suggest that the use of routine cue collection can increase diagnostic accuracy by as much as 15% to 20%, and that early hypotheses generation may be a result of hypothesis directed inquiry. (AEA)

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Doron Gil, Christian C. Wagner
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Simulating the Problem Solving of Reading Clinicians

Doron Gil, Christian C. Wagner, and John F. Vinsonhaler[1]

The major thrust of recent research in teaching views the teacher as a clinical information processor (Shulman, 1975; Shulman & Elstein, 1975). With this in mind, some of the crucial questions to be answered are: How do teachers think? and How does this thinking affect their perception, expectations, diagnostic judgment, prescription, and decision making?

Our research program, part of which is described in this paper, addresses some of these questions specifically. The program is based on a theory of clinical problem solving behavior, originating in medical education research, known as the "Inquiry Theory" (Elstein, Shulman, & Sprafka, 1978; Vinsonhaler, Wagner, & Elstein, Note 1). The Inquiry Theory describes the behavioral domain in which a clinician (e.g., a reading specialist) interacts with a case (e.g., a child with reading difficulties) in order to diagnose the case's problems and recommend an appropriate treatment. The characteristics of this encounter are determined on the one hand by the case, and on the other hand by the clinician's memory and strategy. (The clinician's memory consists of a set of problems, cues, treatments, and the relationships among them, while the strategy is the sequence of mental tasks performed by the clinician.)

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[1]Doron Gil is a research intern with IRT's Clinical Studies group. Christian Wagner is a systems analyst with the Clinical Studies group. John Vinsonhaler, MSU professor in the Department of Counseling and Personal Services, is the coordinator of the Clinical Studies group.

This research is broken down into three different kinds of studies:

1. *Observational studies*, in which reading clinicians and classroom teachers are observed as they interact with simulated cases of children with reading difficulties;

2. *Training studies*, in which the instruction in reading diagnosis and remediation classes is explicitly guided by the Inquiry Theory. This instruction includes the students' interaction with simulated cases and real children with reading difficulties, with computer-based decision aids to guide these interactions; and

3. *Computer simulation studies*, in which simulated clinicians are created to reflect both ideal and typical approaches of reading clinicians to diagnosis and remediation.

The computer simulation of clinical problem solving behavior of reading clinicians is the focus of this paper.

Our research uses the computer to simulate a clinician as s/he interacts with a child having reading difficulties. Throughout this simulated interaction, the computer uses its memory and strategies to arrive at a diagnosis for a child. In so doing, it uses a process of diagnosis similar to the one applied by human clinicians.

The interaction between the computer clinician and a case starts when the computer receives the initial contact about the case, which is some basic information regarding the child's status in reading. Using this information, the computer proceeds to collect more information, on the basis of which it generates some hypotheses about the child's reading problems. Then the simulated clinician checks out these hypotheses using "hypothesis-directed inquiry" (the process of generating hypotheses about the child's problems and collecting information to confirm or disconfirm these hypotheses). After collecting a certain amount of information about the case, the simulated clinician begins its final diagnosis.

In creating different simulated clinicans, different memories and strategies can be used. These different clinicians can then interact

with various cases to reach diagnostic decisions. The effects of these diagnostic outcomes are analyzed, and the increased understanding of the clinical diagnostic process that results can then be applied to the training of human clinicians.

Routine Cue Collection Study

Our first simulation study focused on the impact of routine cue collection on the clinician's performance. Our observational studies with human clinicians have indicated that some clinicians use a routine cue collection procedure (heuristic) at the beginning of every interaction with a new case; other clinicians do not use such a routine. We wanted to know how significant routine cue collection was to the diagnostic process.

To find out, we created simulated clinicians programmed to either use or not use a routine cue collection procedure. Differences in their diagnostic performance were then analyzed. The simulated clinician shown in Figure 1 is an illustration of one using routine cue collection.

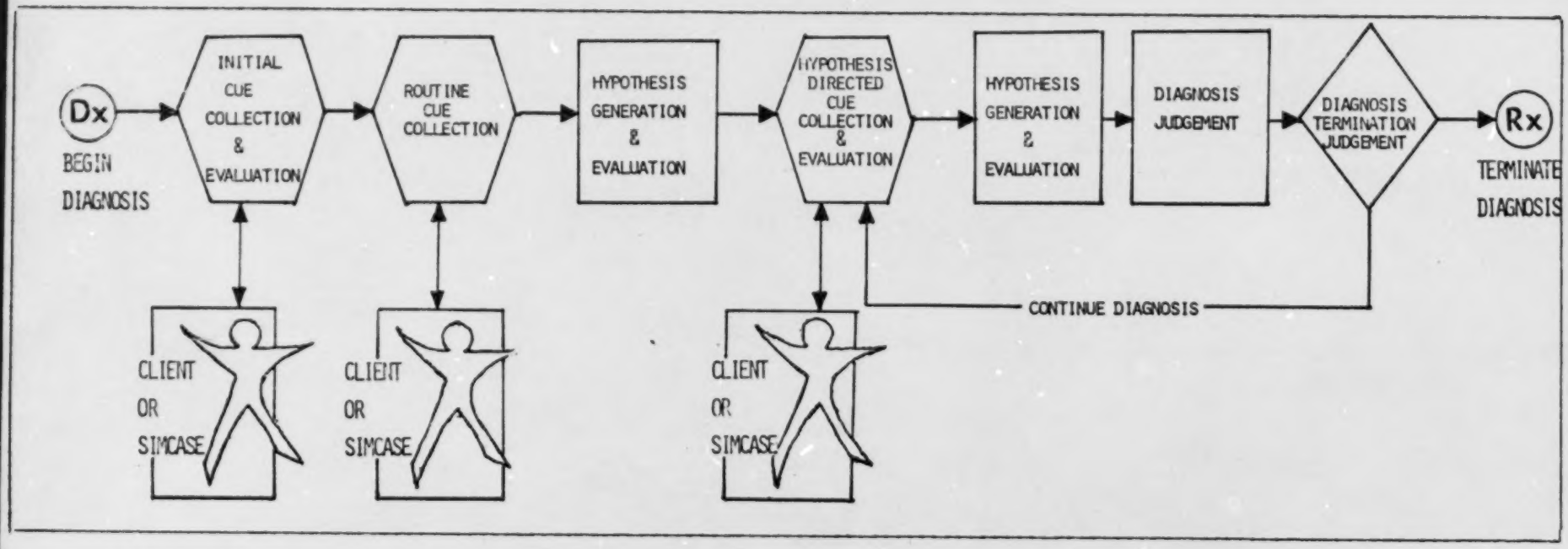

Figure 1: A simulated clinician with routine cue collection.

In Figure 2 there is a simulated clinician identical to the one in Figure 1 except that routine cues are not collected.

Figure 3 shows the performance results for those two simulated clinicians, plus results from human clinicians. The context is the diagnosis of reading problems.

While the average performance was the same for humans and simulated clinicians with routine cue collection (.60 - .70), the range was different (see Figure 3). Human performance ranged from .30 to .90; simulated clinician performance was all close to the mean. Performance of the simulated clinicians without routine cue collection was substantially lower than that of either of the other two groups. In fact, we would predict from the Inquiry Theory that given a good set of routine cues collected prior to initial hypothesis generation, we can expect an improvement in performance of as much as 15 to 20% in diagnostic accuracy.

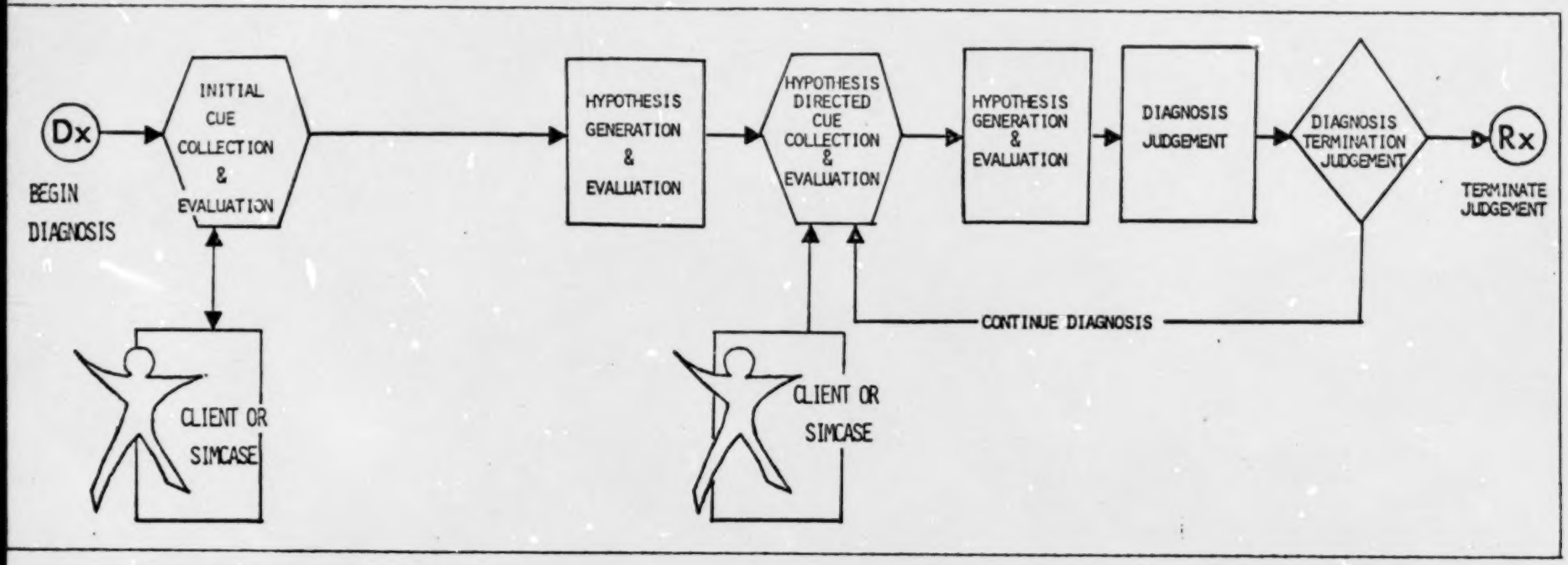

Figure 2: A simulated clinician without routine cue collection.

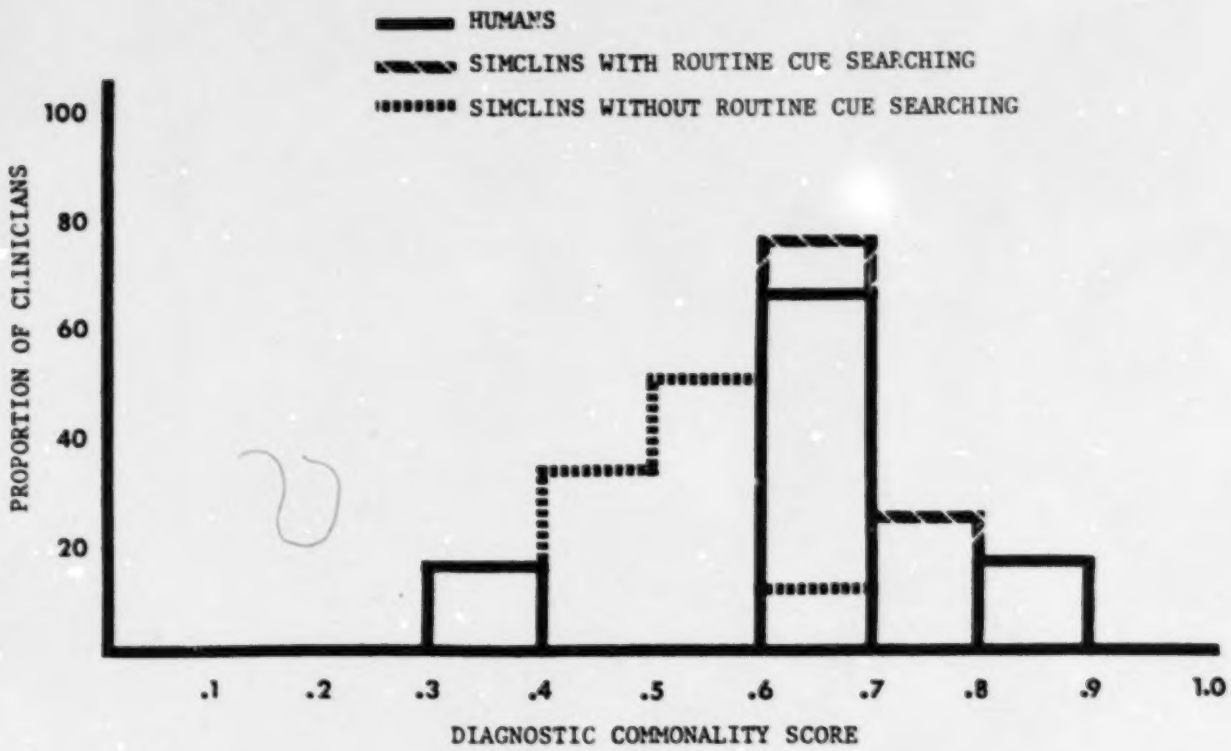

Figure 3: Performance results for simulated clinicians versus humans. The commonality score is a rough measure of the accuracy of diagnosis based on agreement with other (human) clinicians.

Early Hypothesis Generation Study

The second study using simulated clinicians investigated the process of hypothesis generation as it is affected by different certainty thresholds for considering a hypothesis. Hypothesis generation is the process of selecting which hypotheses to consider in the diagnostic workup. The certainty threshold is how likely a hypothesis must be initially to be seriously considered. The higher the threshold during the diagnostic workup, the fewer the hypotheses that will be considered, because more hypotheses will have likelihoods which fall beneath the threshold. The lower the threshold, the greater the number of hypotheses that will be considered, because more hypotheses will have likelihoods above the threshold.

This differentiation between high and low thresholds can be seen in medicine, for example, when students are trained to accept many hypotheses at the beginning of their encounter with a patient, and then narrow these hypotheses down to the most probable ones, studying them very carefully. Students thus trained will be more receptive to new hypotheses early in a session and less receptive as a session proceeds.

To study this phenomenon, we set up a simulated clinician similar to the one in Figure 4. Moving from left to right, note that the clinician first collects the initial contact cues and then routine cues. Second, the clinician generates hypotheses. When the clinician generates hypotheses at this early stage of the interaction, the threshold for hypotheses is low. Therefore, the simulated clinician is very likely to accept many hypotheses. Third, the clinician collects additional cues and again generates hypotheses. However, this time there is a medium threshold level (for accepting new hypotheses). Finally, additional cues are collected and more hypotheses generated, but this time the threshold for hypothesis generation is very high so that the clinician is likely to accept very few new hypotheses. This strategy, then, makes a simulated clinician more receptive to new hypotheses early in the interaction than later in the interaction.

The simulated clinician shown in Figure 5 is a continuous hypotheses generator. This clinician is exactly the same as the one in Figure 4, except that the hypothesis generation threshold remains uniformly low throughout the clinical encounter. Hence, this clinician should be uniformly receptive and should generate as many late as early hypotheses.

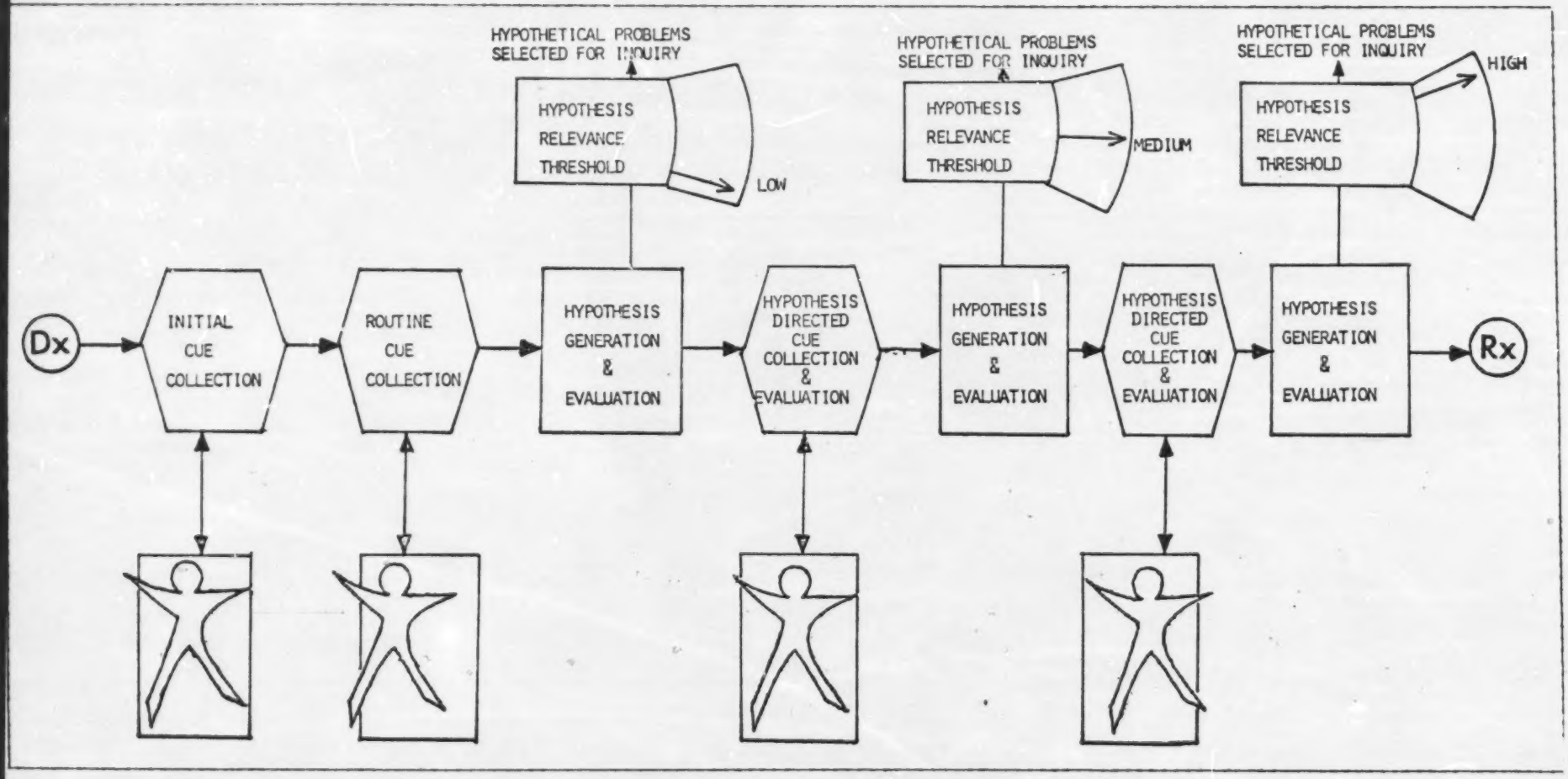

Figure 4: A simulated clinician "favoring" early hypothesis generation.

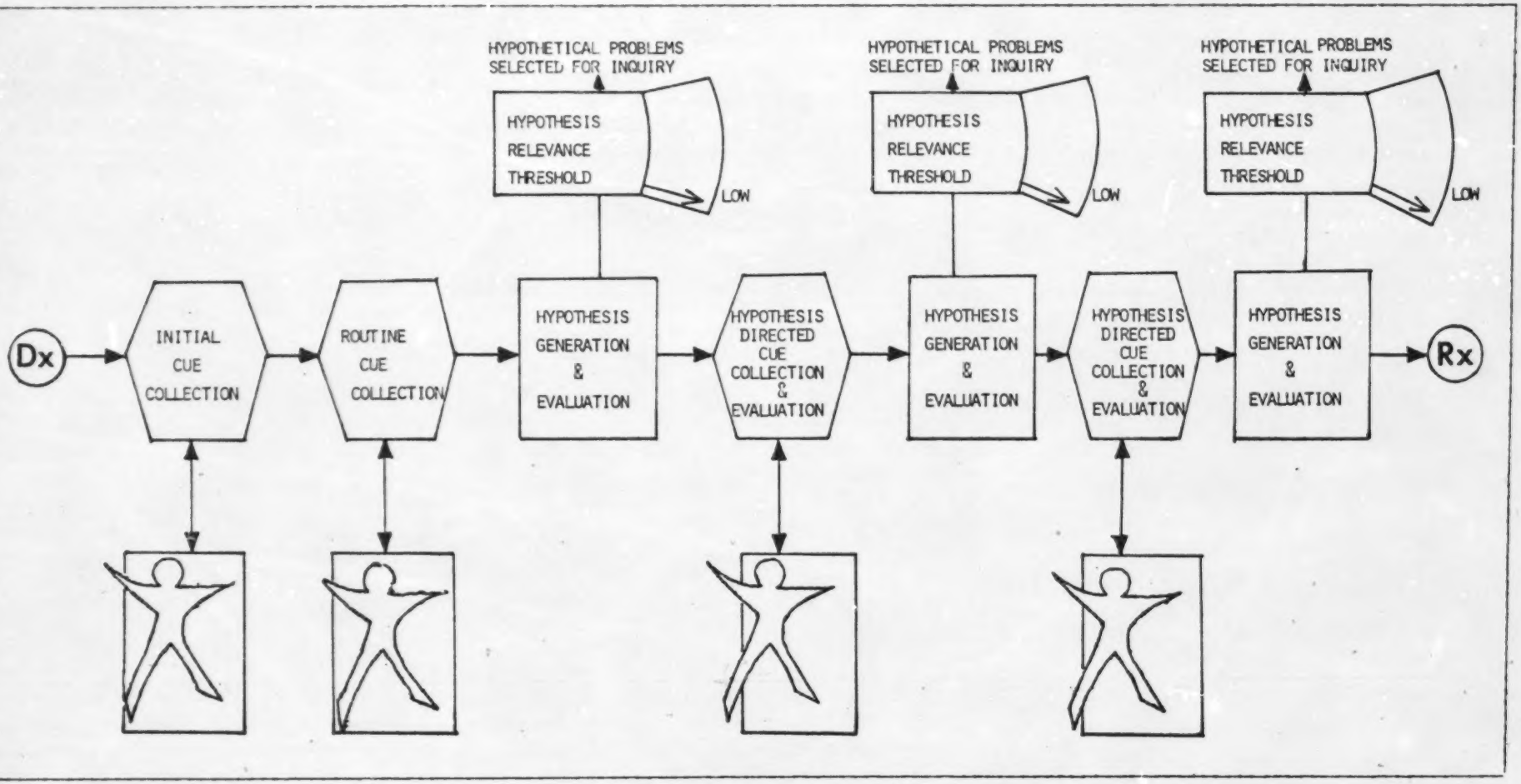

Figure 5: A simulated clinician "favoring" continuous hypothesis generation.

Some of the results of this simulation are presented in Figure 6.

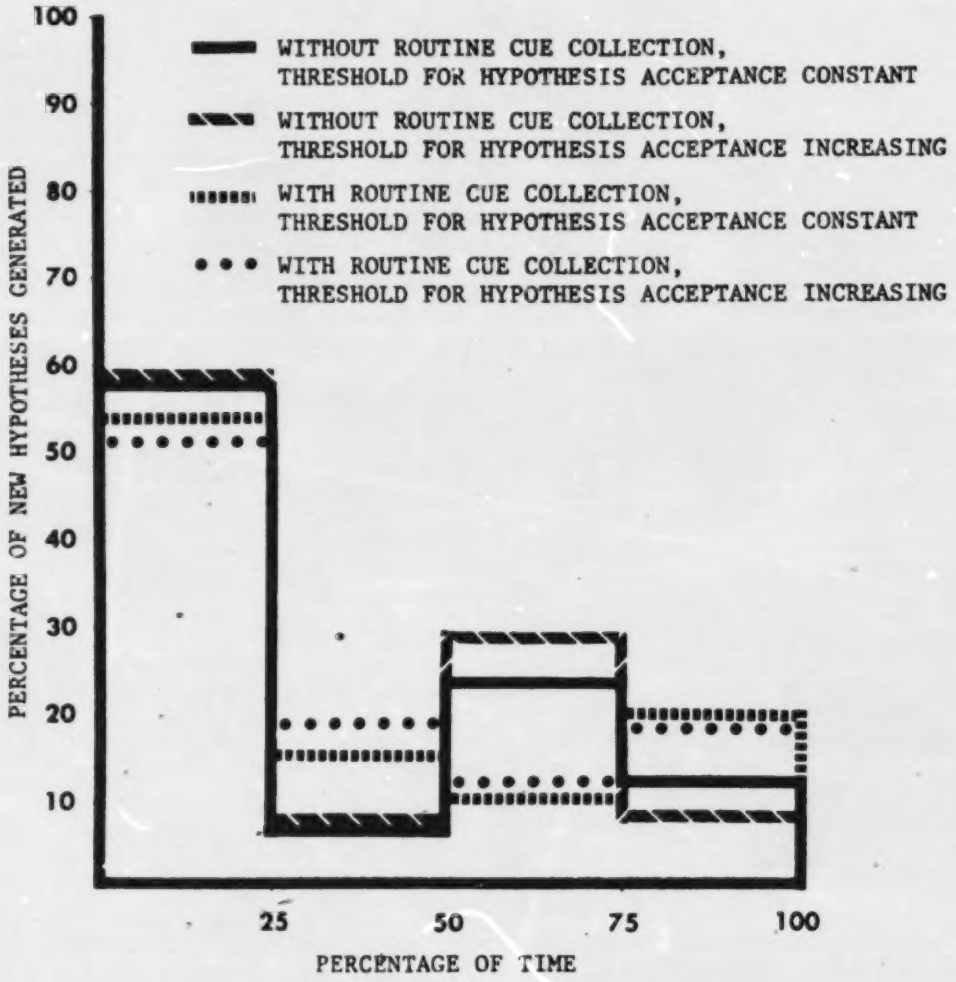

Figure 6: Simulated clinician results.

The horizontal axis indicates the first quarter, second quarter, third quarter, and fourth quarter of the clinical interaction.

A glance at Figure 6 shows that our simulated clinicians, both the uniformly receptive and the early receptive, generate all their hypotheses during the first quarter of the session. This result has characterized many similar studies of early hypothesis generation.

We are coming to the conclusion that early hypothesis generation is a necessary consequence of the Elstein-Shulman (Elstein, et al, 1973) Theory of Inquiry. That is to say, a clinician who is a hypothesis

directed inquirer (i.e., a deductive reasoner) is an early hypothesis generator. The mechanism responsible for this result is probably sampling without replacement. That is, given a limited problem space with a fixed number of diagnostic possibilities, the clinician tends to generate many of the relevant hypotheses early in the session, and by the time s/he has gone down to the end of the session, s/he has simply run out of hypotheses to generate, given the defined problem space. This finding is especially relevant to our studies in reading. Reading clinicians exhibit late or continuous hypothesis generation. The above finding may indicate that these clinicians (along with some physicians) are not using deductive reasoning (i.e., operating from an hypothesis-directed strategy). Rather, they are using an inductive reasoning strategy, first collecting fixed or probabilistically chosen sets of cues, then interpreting the results by generating hypotheses and judging them for diagnosis.

Conclusion

In conclusion, these studies exemplify the type of information to be gained by computer simulation studies. These studies suggest that the use of routine cue collection increases diagnostic effectiveness, and that early hypotheses generation may be a result of hypothesis-directed inquiry. These behaviors may be important to an effective diagnostic process, and both should be considered in the training of physicians, teachers, and other clinicians on diagnostic skills.

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